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A STUDY ON PHYTOEXTRACTION OF TOXIC HEAVY METALS FROM THE SOIL BY CORN (ZEA MAYS)

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ABSTRACT

The aim of the present study is to determine the effectiveness of phytoremediation in the removal of heavy metals using corn. In our study Soil sample collected at a depth of 20 cm were taken from different polluted areas. The experiment consists of 3 treatments each containing 1kg of soil including soil without concentrations of Cr, Mn and Pb to serve as the control. 3 pots each were contaminated with 2.5 g/dm3 concentration of Cr, Mn and Pb. The initial analysis of the soil indicates that the uncontaminated soil sample contained 1.77 mg/kg of Cr, 32 mg/kg of Mn and 0.15 mg/kg of Pb while the contaminated soil sample contained 15.7 mg/kg of Zn, 49 mg/kg of Mn and 4.35 mg/kg of Pb. 4 corn seeds were planted on each of the soil samples at a depth of 4cm and the setup was monitored properly in an isolated place. Samples were taken for analysis at 2 weeks interval of 6 weeks. Results show that at the end of the 4 weeks, there was reduced in the concentration of the heavy metals in the soil and there was an increase in the level of heavy metals in the plant leaves and stems. The plants were more tolerant of the heavy metals as they had a fast growth, therefore it was concluded that corn is the very good hyper accumulator and it is effective in the removal and detoxification of soil contaminated with heavy metals.

Keywords: Phytoremediation, Chromium, lead, Manganese, heavy metals

Introduction

Due to rapid urbanization and development of industries are major factors for the contamination of soil. Soil located in Industrialized regions have been identified as the most affected area due to the heavy metals they used for production and manufacturing. Soil pollution spread to other parts of the natural environment because soil lies at the confluence of many natural systems [1-3]. Many human diseases result from the buildup of toxic metals in soil, making remediation of these areas crucial in the protection of human health [4-7]. Risk reduction can be through a process of removal, degradation or containment of contaminants. However long term application of heavy metals such as cadmium (Cd), chromium (Cr), Lead(Pb), and Zinc (Zn), in soil causes decline in soil microbial activity, soil and groundwater contamination, reduction in soil fertility and contamination of human food chain [8-10].

Heavy metals, especially lead, are major environmental pollutants that pose a serious threat to the environment and human and animal health [11]. Heavy metal contamination of soil environment occurs for centuries but its extent has increased markedly in the last fifty years due to technological developments and increased consumer use of materials containing these metals [12].

Current methods of soil remediation such as soil washing, mechanical separation, extraction and storage do not really solve the problem. Hence the need for alternative, cheap and efficient methods to clean up heavily contaminated industrial areas. The current remediation techniques of heavy metal from contaminated soil water are expensive, time consuming and environmentally destructive. Unlike organic compounds, metals cannot degrade and therefore effective cleanup requires their immobilization to reduce or remove toxicity. In recent years, scientist and engineers have started to generate cost effective technologies such as adsorbents. Plants are an effective means of removal of contaminants from soil [13]. Phytoremediation is a general term for using

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plants to remove, degrade or contain soil pollutants such as heavy metals, pesticides, solvents, crude oil, polyaromatic hydrocarbon and landfill leacheates.

Phytoremediation is therefore an emerging technology for cleaning up of contaminated and is now a widely supported green technology which may provide an alternative to cleaning wastewater and contaminated soil. It is a cost effective, environmentally friendly and aesthetically pleasant nature and equal applicability for the removal of both organic and inorganic pollutants present in soil, water and air [12].

A major factor influencing the efficiency of phytoremediation is the ability of plants to absorb large quantities of metal in a short period of time. Corn (Zea mays) planted on the contaminated soil had higher levels of heavy metals than the one planted on the uncontaminated soil. The difference indicates that they have been absorbed away from the contaminated soil [12]. Zea mays is thus a hyper accumulator of heavy metal, tolerant of the targeted metals and also had a fast growth rate [13]. This present study focus on evaluating the performance of corn as an hyperaccumulator in the removal of heavy metals from soil.

Soil Sampling

Soil sample was collected from polluted area at a depth of 20cm. Four fresh corn seeds were planted in pots containing 4 kg of the soil at a depth of 4 cm. The experiment consists of 4 treatments, each of these treatment were divided into 3 replicates to give a total of 12 pots. 3 pots without zinc, iron and lead to serve as control, 3 pots contaminated with 2.5 g/dm^3 concentration of Cr, 3 pots contaminated with 2.5 g/dm^3 concentration of Manganese and 3 pots contaminated with 2.5 g/dm^3 concentration of Lead. All the soil samples were taken for initial analysis. After 6 weeks of seed planting and germination, samples from the contaminated soil and the control were analyzed at two weeks interval for heavy metal content. At the end of the 6 weeks, the plants were uprooted and the stems and leaves were also analyzed for the heavy metal uptake.

Soil preparation

During study Soil preparation done by two different; soil pre-treatment and soil digestion.

Soil Pre-treatment

The soil samples were grounded by using Agate mortar to enhance the oxidation of soil samples and it was passed through a 0.25 mm sieve mesh to obtain a fine particle.

Soil Digestion

For the digestion of soil samples we are used nitric acid digestion, nitric acid-sulphuric acid digestion, nitric acid-perchloric acid digestion, wet ashing digestion and microwave digestion. In this experiment the nitric acid-perchloric acid digestion was utilized. 0.5g of the finely grounded soil sample was accurately weighed using a digital weighing balance and placed in a 50ml beaker. 20ml of a mixture of nitric acid and perchloric acid in 1:1 molar ratio was poured into the soil in the beaker and the content was placed on a hot plate and heated gently at low temperature until dense white fumes of $HClO_3$ appears. After the digestion , digested sample was allowed to cool before it was filtered into a 50ml standard volumetric flask which was made up to mark with distilled water and the sample ware placed in storage containers and taken for analysis using atomic absorption spectrometer.

Soil Analysis

The soil was analysed using an atomic absorption spectrometer (AAS). The Sample was aspirated into a flame, atomized and a light beam was directed through the flame into a monochromator and a detector measured the amount of light absorbed by the atomized element in the flame.

Results

The study is mainly focus on evaluating the effectiveness of corn as a phytoremediating agent in the removal of toxic heavy metal from soil. The results of the study conducted in period of 6 weeks are presented in tables and figures. The concentrations of Cr, Mn and Pb over a period of 6 weeks at 2 weeks interval are

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presented in Tables 1- 4 while the results obtained on the leaves and stems after 6 weeks are presented in Tables: 5 and 6. The result of the percentage absorbance of the heavy metal in the leaves and stems of the plant at the end of the 6 week period are presented as Figure: 1.

Table 1. Sample at initial stage

Treatment	Cr (mg/kg)	Mn (kg/mg)	Pb (kg/mg)
Control	1.77	32	0.15
T1	15.7	49	4.35
T2	16.5	49.2	4.11
T3	17	41.5	4.05

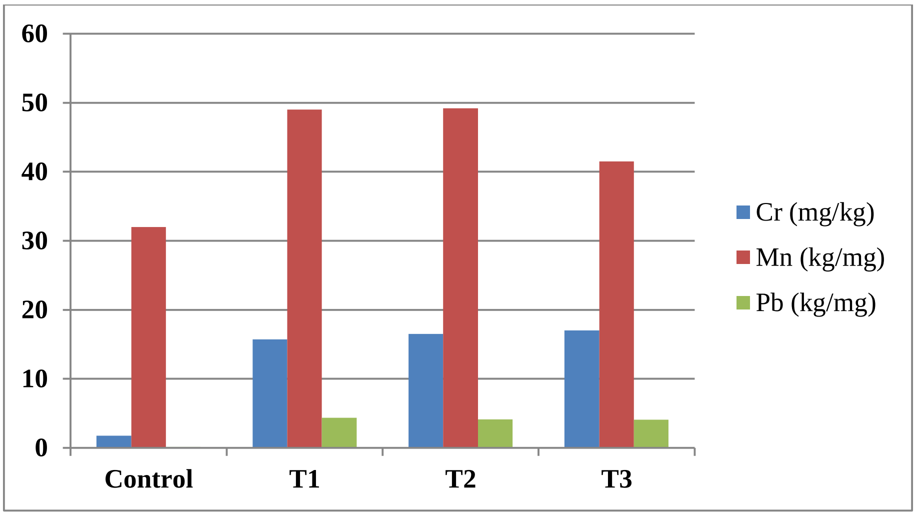

Fig 1. . Sample at initial stage

Table 2. Sample at 2 nd week

Treatment	Cr (mg/kg)	Mn (kg/mg)	Pb (kg/mg)
Control	0.72	16	0.12
T1	13.5	27.5	3.20
T2	14.5	33.5	3.0
T3	13	35	3.25

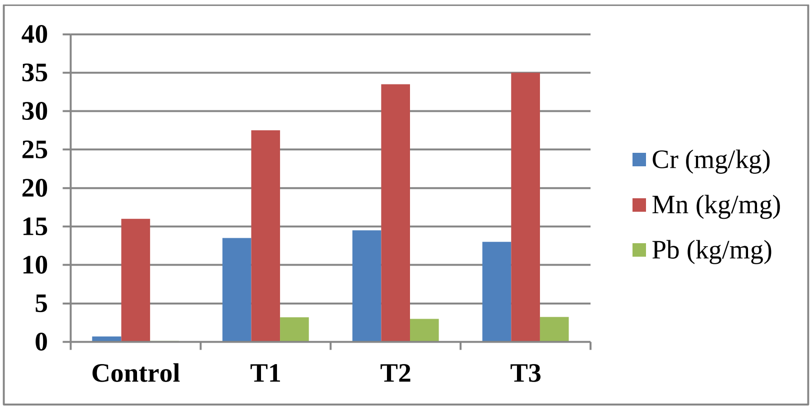

Fig 2. . Sample at 2 nd week

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Table 3. Sample at 4 th week

Treatment	Cr (mg/kg)	Mn(kg/mg)	Pb (kg/mg)
Control	0.46	12	0.09
T1	12	20.5	1.75
T2	13	22.5	1.65
T3	9.25	21	1.85

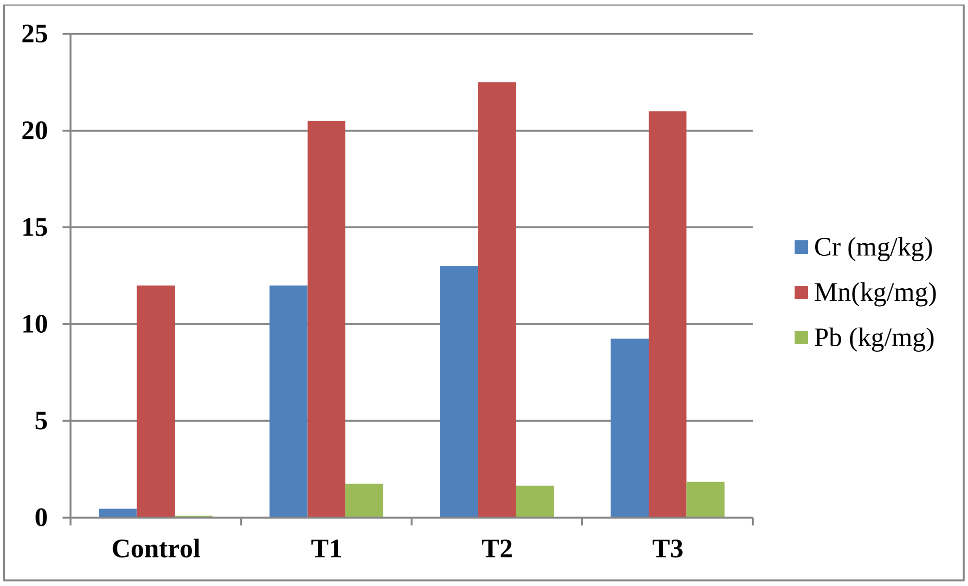

Fig 3. Sample at 4 th week

Table 4. Sample at 6 th week

Treatment	Cr (mg/kg)	Mn (kg/mg)	Pb (kg/mg)
Control	0.27	7.5	0.03
T1	6.70	12	1.00
T2	6	16	0.95
T3	4.5	14	1.20

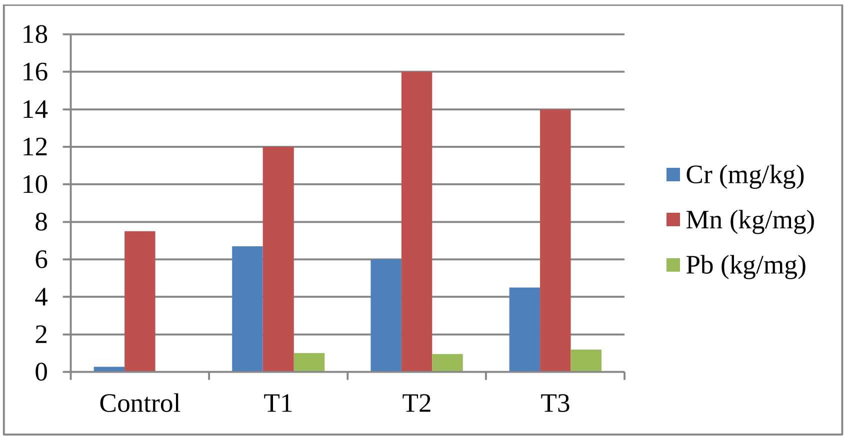

Fig 4. Sample at 4 6th week

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Table 5. Results of levels of toxic heavy metals in leaves of the corn after 6 weeks

Treatment	Cr (mg/kg)	Mn (kg/mg)	Pb (kg/mg)
Control	0.40	4.20	0.02
T1	2.35	6.50	0.45
T2	2.00	7.25	0.57
T3	2.03	7.45	0.60

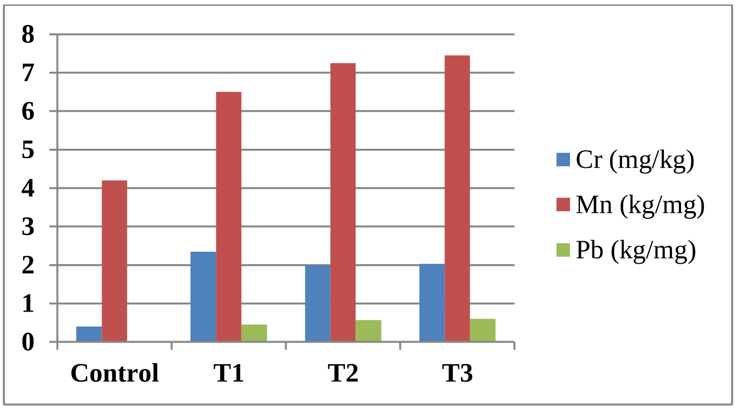

Fig 5. of levels of toxic heavy metals in leaves of the corn after 6 weeks

Table 6. Results of levels of toxic heavy metals in stem of the corn after 6 weeks

Treatment	Cr (mg/kg)	Mn (kg/mg)	Pb (kg/mg)
Control	0.32	4.35	0.04
T1	2.10	6.80	0.65
T2	1.85	7.50	0.75
T3	1.95	7.90	0.55

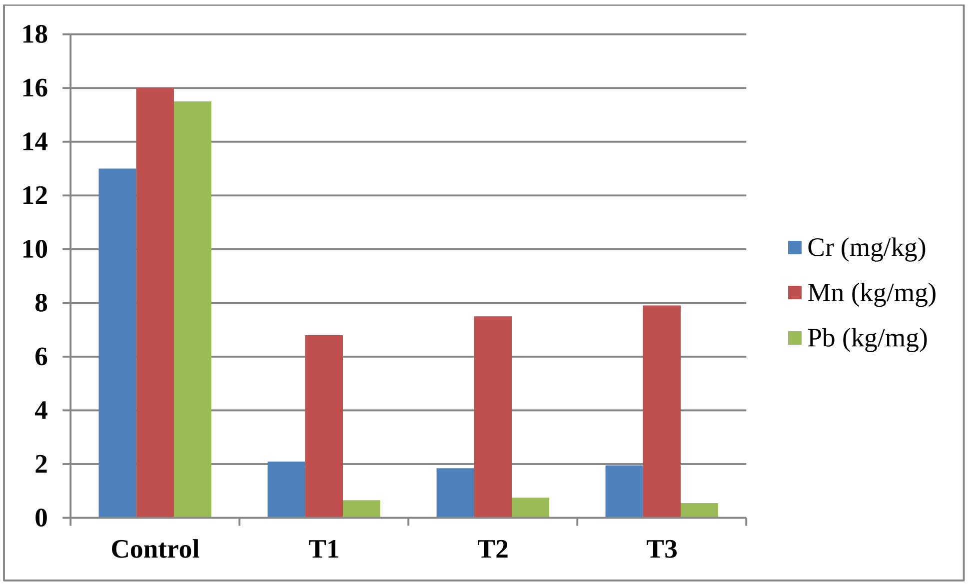

Fig 6. Levels of toxic heavy metals in stem of the corn after 6 weeks

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Discussion

Table 1 to 4 shows the level of toxic heavy metals concentration found in the control and contaminated soil samples in 2 weeks interval in a space of 6 weeks. Table: 5 and 6 shows the level of toxic heavy metal in the stem and leave of the harvested plant sample. Figure: 1 to 4 shows the comparative reduction in the level of toxic heavy metals in soil over the study period of 6 weeks. Table: 1 shows the average concentration of Cr, Mn and Pb at the initial stage was 1.77 mg/kg, 32 mg/kg and 0.15 mg/kg respectively. These results revealed that their level in a soil that is not contaminated and from the result it can be deduce that manganese has a high concentration in an uncontaminated soil. Also, the average concentration of Cr, Mn and Pb at the initial stage in the contaminated soil was 116.46 mg/kg, 42.92mg/kg and 3.16 mg/kg respectively which is considerably high for a contaminated soil.

In the present study, Table: 2 shows the result of the sample at the end of the 2nd week of experiment. The concentration of Cr, Mn and Pb in the uncontaminated soil is 0.72 mg/kg, 16 mg/kg and 0.12 mg/kg respectively and their average levels in the contaminated soil are 13.66 mg/kg, 32 mg/kg and 3.15 mg/kg respectively. These indicate a comparative reduction of the heavy metals ion both the controlled and contaminated soil which can be attributed to the transport of the heavy metal into the roots of the plant [14].

Table: 3 shows the result of the sample at the end of the 4th week of experiment. The concentration of Cr, Mn and Pb in the uncontaminated soil is 0.46 mg/kg, 12 mg/kg and 0.90 mg/kg respectively and their average levels in the contaminated soil are 10.75 mg/kg, 21.33 mg/kg and 1.75 mg/kg respectively. These also indicates a comparative reduction of the heavy metals in both the controlled and contaminated soil which show more amount of the heavy metals have been absorbed in the corn(Zea Mays).

Table 4: shows the result of the sample at the end of the 6th week of experiment. The concentration of Cr, Mn and Pb in the uncontaminated soil is 0.27 mg/kg, 7.50 mg/kg and 0.03 mg/kg respectively and their average levels in the contaminated soil are 5.73 mg/kg, 14 mg/kg and 1.05 mg/kg respectively. These also indicates a comparative reduction of the heavy metals in both the controlled and contaminated soil which show more amount of the heavy metals have been absorbed in the corn (Zea Mays) [15].

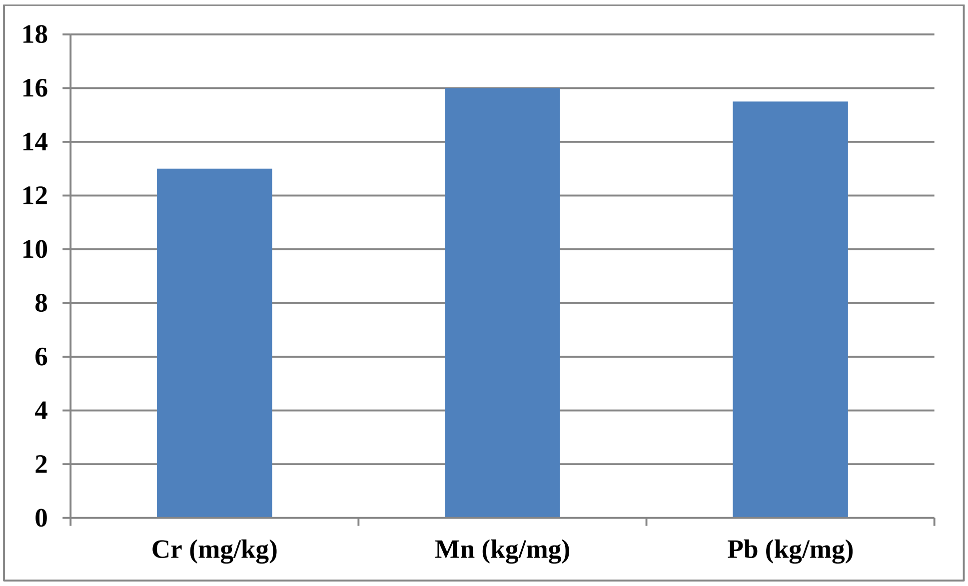

Fig 7. Percentage Absorbance of Heavy Metals in leaves of Corn on Controlled soil sample after 6 weeks

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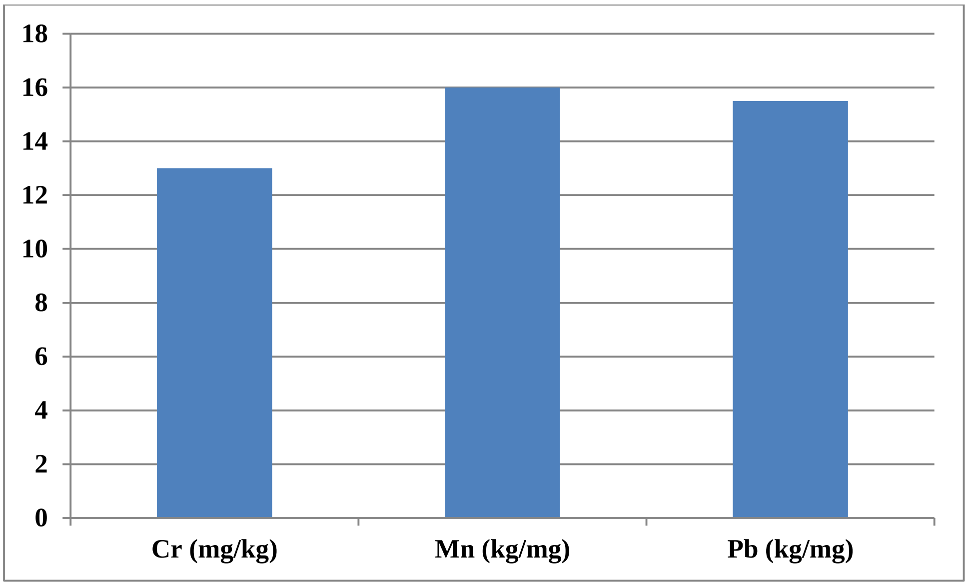

Fig 8. Percentage Absorbance of Heavy Metals in leaves of Corn on Contaminated soil sample after 6 weeks

From Figure 5, the percentage absorbance of Cr, Mn and Pb into the leaves of the plant is 22 %, 17 % and 16 % respectively of their initial concentration from the controlled soil sample into the leaves. In Figure 2, there was an uptake of 13 % Cr, 16 % Mn and 15.5 % Pb of the initial concentration from the contaminated soil sample into the leaves of the corn. From these results, it can be deduce that Cr has the highest absorption rate into the leaves from the controlled soil sample and Mn has the highest absorption rate into leaves of the contaminated soil sample.

From these results, it can be deduce that Cr has the highest absorbance rate into the stem from the controlled soil sample and Mn has the highest absorbance rate into the stem from the contaminated soil sample. The results also pointed out that the level of the heavy metals in the stem were more than their amount in the leaves which can be attributed to the further transportation of the heavy metals from the stem to the leaves. The highest removal of Cr concentration in the contaminated soil sample was in the sixth week period and the highest removal of Mn and Pb was in the Fourth week.

From all these result obtained, it shows there was a steady decrease in the levels of the heavy metals in both the controlled and contaminated soil sample and an increase in the levels of these heavy metals in the leaves and stem of the corn accompanied by their corresponding decrease in soil sample indicate that they are accumulating into the corn through its root. The increase in the levels of these heavy metals in the corn sample can be attributed to two major transport mechanisms: convection and diffusion [16]. There is a transport of soluble metal ions from the soil solid to the root surface due to convection because as water is being lost by the leaves due to transpiration. There is need of replacement of these water from the soil, these water loss to the atmosphere create a concentration gradient thereby driving the diffusion of ions towards the depleted layer of the plant thereby creating a movement from the soil into the roots, stems and leaves. Some ions are absorbed by roots faster than the rate of the supply [17].

Conclusion

Maize (*Zea mays* L.) is a widely cropped annual cereal that grows rapidly, produces extensive fibrous root system with large shoot biomass yield per hectare, withstands adverse conditions, and produces abundant seeds with ease of cultivation under repeated cropping. The crop is heavy-metal tolerant, has high metal accumulating ability in the foliar parts with moderate bioaccumulation factor. Given these attributes, maize is

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capable of continuous phytoextraction of metals from contaminated soils by translocating them from roots to shoots. Certain metals (e.g.Cd and Pb) have been reportedly accumulated by the crop above the level used to define metal hyperaccumulation The potential use of maize, a robust tropical cereal crop inphytoextraction technology and possible utilization of the by-product is advocated especially for developing countries with scarce funds available for environmental restoration.

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